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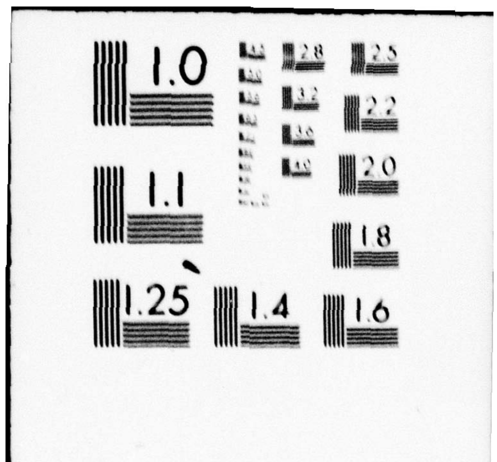

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by

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The modification fabrication and test of magnetometers and digital equipment is described.

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Joseph D. Means

Robert C. Snare

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1. Contract Objectives

The purpose of the contract was to fabricate additional equipment for the Air Force Geophysics Laboratory magnetic data collection system. The system was designed and original equipment was fabricated by UCLA under contract F19628-72-C-0175.

The contract requires design studies and fabrication of three fluxgate magnetometers and two data collection platform digital systems.

2. Fluxgate Magnetometers Fabrication

The fluxgate magnetometers followed the design of Power [1] with modifications to reduce digital noise on the analog outputs of the magnetometer. The changes included better power supply decoupling on the drive boards, reduced frequency response of the summing amplifiers on the second harmonic boards and the design of a new display logic board.

The redesigned display logic board (figure 1) uses fewer digital logic circuits that require less power and introduce less noise into the magnetometer circuits.

The sensor cables were fabricated from specially ordered wire having a water proof outer cover. Three cables fabricated for the new magnetometers and six additional cables were fabricated for retrofitting the magnetometers built under the earlier contract.

A new sensor assembly was fabricated for magnetometer SN001 and the unit redesignated SN001A. This sensor assembly was designed to minimize cross axis sensing between the three orthogonal sensors in the assembly.

3. Data Collection Digital Equipment Fabrication

The data collection platform digital equipments were fabricated to the original design of Ioannidis et al. [2]. The two units incorporated analog-to-digital

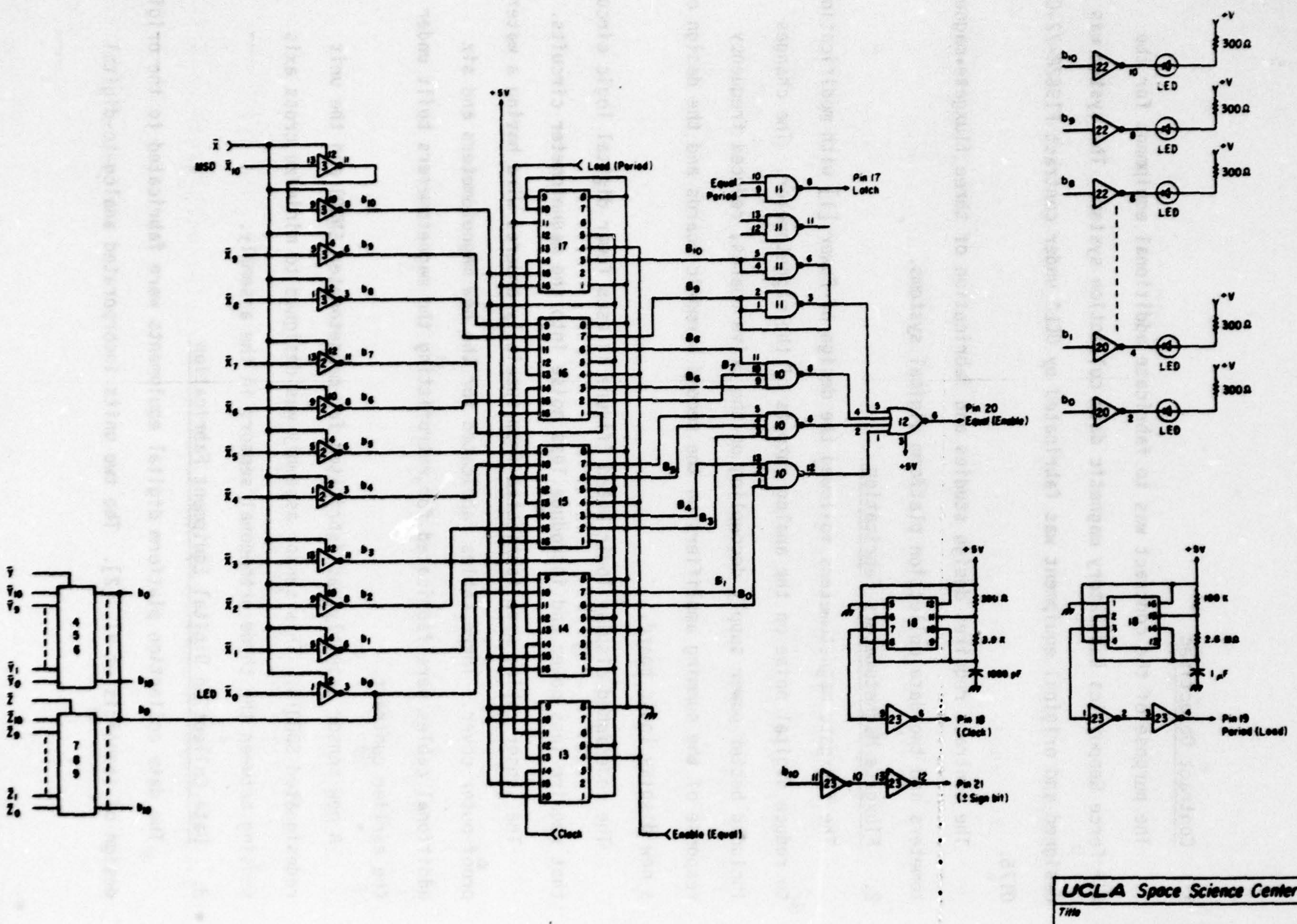

Figure 1. Display logic board schematic

converters manufactured by Tustin Electronics of Irvine, California. The two units are fully compatible and interchangable with equipment fabricated under the earlier contract.

4. Magnetometer Tests

The final tests of the magnetometers were conducted in two parts. At NASA Ames Research Center the orthogonality of the sensors and the scale factor were tested. In the laboratory at UCLA the relative temperature dependence of the sensor assembly and the electronics were tested.

The test procedure for the orthogonality and scale factor tests and the data for magnetometers SN007, SN008, SN009 and SN001A are shown in Table I. These test were performed at NASA Ames Research Center because of the good quality of the magnetic test facility. The facility has a 12 foot cubical coil system driven by precision current sources. The alignment and the scale factors of the system are periodically checked.

The temperature test procedures and data are shown in Table II and Table III. This test demonstrates the relative temperature dependence of the system. With the limited size of the coils in the UCLA magnetic test facility, 30 inch in diameter, it is difficult to make three axis measurements approaching absolute accuracy.

The sensor temperature test is performed in two runs, one hot and one cold. Because the sensor is moved between the two runs of the test the data at room temperature does not close for some cases. This is because the sensor is not aligned exactly to the same position within the coil system between the two runs.

Table I

Magnetometer Test Outline

1. Sensor alignment checks

1.1 Place sensor assembly in the center of the coil system with the X-axis pointing north. Adjust leveling screws to zero the level bubbles on the sensor.

1.2 Adjust the field such that each magnetometer reads zero.

1.3 Increase the E-W field to ~10,000γ and rotate the sensor till the X-axis reads zero. Relevel the sensor if needed and repeat the X zero test. The sensor assembly is now level with the X sensor aligned with the N-S coil. Remove the 10,000γ E-W field.

1.4 Adjust the field such that each magnetometer axis reads zero.

1.5 Increase the N-S field to 10,000γ and record the Y and Z magnetometer axes. Remove the field.

1.6 Increase the vertical field to 10,000γ and record the X and Y magnetometers. Remove the field.

1.7 Increase the E-W field to 10,000γ. Record the X and Z axes magnetomerer. Remove the field.

1.8 Adjust the field such that the X magnetometer reads zero. Apply the following calibrate fields in the N-S axis, +40,000γ.

1.9 Repeat the values of 1.8 for the vertical coils and record the Z magnetometers.

1.10 Rotate the sensor 90^{0} in the horizontal plane using the technique of 1.3 to align the Y axis to the N-S coil.

1.11 Repeat the values of 1.8 for the N-S coils recording the Y-axis.

1.12 Stand the sensor on its + Y edge (the cable side). Align the X-axis to north by zeroing X with a large E-W field.

1.13 Increase the vertical field to 10,000γ and record the X magnetometer.

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Data Sheet

1.5. $Y = \underline{-24}\ \gamma$ S 10878

$Z = \underline{+15}\ \gamma$

$\theta = \sin^{-1} \frac{Y}{10{,}000} = \underline{-7.6 \text{ min}}$

θ = Y sensor alignment error projected into X-Y plane

$\phi = \sin^{-1} \frac{Z}{10{,}000} = \underline{4.7 \text{ min}}$

ϕ = Z sensor alignment error projected into X-Z plane

1.6 $X = \underline{-13}\ \gamma$ ↓ 9993

$Y = \underline{-6}\ \gamma$

$\delta = \sin^{-1} \frac{X}{10{,}000} = \underline{4.5 \text{ min}}$

δ = X sensor alignment error projected into X-Z plane

$\tau = \sin^{-1} \frac{Y}{10{,}000} = \underline{2.1 \text{ Min}}$

τ = Y sensor alignment error projected into Y-Z plane

1.7 $X = \underline{+9}\ \gamma$ E 26470

$Z = \underline{+42}\ \gamma$

$\gamma = \sin^{-1} \frac{X}{10{,}000} = \underline{1.2 \text{ min}}$

γ = X sensor alignment error in X-Y plane

$\xi = \sin^{-1} \frac{Z}{10{,}000} = \underline{5.4 \text{ min}}$

ξ = Z sensor alignment error in X-Z plane

1.8 N-S Calibrate Field X Magnetometer

+40,000γ 21763.6 21763.6 γ

-40,000γ ____ γ

1.9 Vertical Field Z Magnetometer

+40,000γ 43506.7 43506.7 γ

-40,000γ -43538 -43538 γ

1.11 N-S Field Y.Magnetometer

+40,000γ +21763.6 +21763.6 γ

-40,000γ ____ γ

1.13 X = +26 γ ↓ 10,000γ

$$\rho = \sin^{-1} \frac{X}{10{,}000} = 8.9 \text{ min}$$

ρ = alignment error of X sensor from baseplate edge in X-Y plane

Data Sheet SN007

1.5 γ = +29 γ NS = 108008 S

Z = +22 γ Y_0=1.2 Z_0 = +2.5

$\theta = \sin^{-1} \frac{Y}{10,000}$ = 0.15°

θ = Y sensor alignment error projected into X-Y plane

$\phi = \sin^{-1} \frac{Z}{10,000}$ = 0.12°

ϕ = Z sensor alignment error projected into X-Z plane

1.6 X = −57 γ V = 104908 DN

Y = −4.8 γ

$\delta = \sin^{-1} \frac{X}{10,000}$ = 0.32

δ = X sensor alignment error projected into X-Z plane

$\tau = \sin^{-1} \frac{Y}{10,000}$ = 0.03

τ = Y sensor alignment error projected into Y-Z plane

1.7 X = +3 γ X_0 = +4.7 EW = 105408 E

Z = +28 γ

$\gamma = \sin^{-1} \frac{X}{10,000}$ = 0.02°

γ = X sensor alignment error in X-Y plane

$\xi = \sin^{-1} \frac{Z}{10,000}$ = 0.15°

ξ = Z sensor alignment error in X-Z plane

1.8 N-S Calibrate Field X Magnetometer

~~+40,000~~ γ +21749 γ $\underline{+21749.}$ γ

1.9 Vertical Field Z Magnetometer

~~+40,000~~ γ +43501 $\underline{+43501}$ γ

1.11 N-S Field Y Magnetometer

~~+40,000~~ γ +21749 γ $\underline{+21749}$ γ

1.13 X = $\underline{+163}$ γ $X_0 = -4.28$ 10400800 P

$\rho = \sin^{-1} \frac{X}{10,000} = \underline{.8895^\circ}$

ρ = alignment error of X sensor from baseplate edge in X-Y plane

Data Sheet

S N008

1.5 Y = -51 γ $Y_0 = -12$ 10744 ES

Z = +56 γ $Z_0 = -23$

$\theta = \sin^{-1} \frac{Y}{10,000}$ = .336°

θ = Y sensor alignment error projected into X-Y plane

$\phi = \sin^{-1} \frac{Z}{10,000}$ = .144°

φ = Z sensor alignment error projected into X-Z plane

1.6 X = -72 γ $X_0 = +6$

Y = -56 γ $Y_0 = -16$ 99188 up

$\delta = \sin^{-1} \frac{X}{10,000}$ = .381°

δ = X sensor alignment error projected into X-Z plane

$\tau = \sin^{-1} \frac{Y}{10,000}$ = .231°

τ = Y sensor alignment error projected into Y-Z plane

1.7 X = -16 γ $X_0 = +7$ 107378E

Z = -52 γ $Z_0 = -26$

$\gamma = \sin^{-1} \frac{X}{10,000}$ = .091°

γ = X sensor alignment error in X-Y plane

$\xi = \sin^{-1} \frac{Z}{10,000}$ = .139°

ξ = Z sensor alignment error in X-Z plane

1.8 N-S Calibrate Field X Magnetometer

+40,000γ +43529γ +43528 γ

1.9 Vertical Field Z Magnetometer

+40,000γ 43530 +43531 γ

1.11 N-S Field Y Magnetometer

+40,000γ 43532 43528 γ

1.13 X = −128 γ $X_0 = -10$ 10005 8UP.

$$\rho = \sin^{-1} \frac{X}{10{,}000} = .675°$$

ρ = alignment error of X sensor from baseplate edge in X-Y plane

SNOOJ

Data Sheet

1.5. $Y =$ + 19 γ Y_o -12 109208.5

$Z =$ -43 γ Z_o -4

$\theta = \sin^{-1} \frac{Y}{10,000} =$ .110°

θ = Y sensor alignment error projected into X-Y plane

$\beta = \sin^{-1} \frac{Z}{10,000} =$ .205°

β = Z sensor alignment error projected into X-Z plane

1.6 $X =$ -77 γ X_o +1 9935 γ UP

$Y =$ -82 γ Y_o -12

$\delta = \sin^{-1} \frac{X}{10,000} =$ .449

δ = X sensor alignment error projected into X-Z plane

$\tau = \sin^{-1} \frac{Y}{10,000} =$ .403

τ = Y sensor alignment error projected into Y-Z plane

1.7 $X =$ +5 γ X_o +1 10453. γ E

$Z =$ -9 γ Z_o -8

$\gamma = \sin^{-1} \frac{X}{10,000} =$ .022°

γ = X sensor alignment error in X-Y plane

$\xi = \sin^{-1} \frac{Z}{10,000} =$ .033°

ξ = Z sensor alignment error in X-Z plane

1.8 N-S Calibrate Field

$+40,000\gamma$ +43530.8

X Magnetometer

43530.8 γ $X_0 = -4$

1.9 Vertical Field

$+40,000\gamma$ 43530.8

Z Magnetometer

43532. γ

1.11 'N-S Field

$+40,000\gamma$ +43530.8

Y.Magnetometer

43531. γ

1.13 X = + ~~292~~ 496 γ

9975 8UP

$\rho = \sin^{-1} \frac{X}{10,000}$ = .557°

ρ = alignment error of X sensor from baseplate edge in X-Y plane

Table II

Electronic Temperature Test

1. Align the sensor assembly in the coil system.
2. Install the electronics in the temperature chamber.
3. Adjust the field in each coil to zero the magnetometer.
4. Set the temperature control to the desired temperature.
5. After temperature stabilization apply plus and minus 10,000γ to each axis in succession.
6. Read and record the output of each axis of the magnetometer.

SN008 Electronics Temp Test

Te	X	Y	Z
$53^{o}C$	+10639γ	+11475γ	+9971γ
	-10631	-11469	-9971
40	+10638	+11470	+9970
	-10631	-11467	-9969
34	+10637	+11469	+9967
	-10630	-11464	-9968
28	+10637	+11466	+9968
	-10630	-11463	-9966
23	+10636	+11464	+9967
	-10629	-11461	-9966
17.5	+10637	+11461	+9964
	-10629	-11457	-9964
12.5	+10637	+11459	+9961
	-10630	-11458	-9963

SNOOB Electronics Temp Test

Te	X	Y	Z
+15°C	+10124γ	+9858γ	+9886γ
	-10124	-9858	-9884
+20	+10124	+9858	+9887
	-10123	-9859	-9884
+24	+10123	+9859	+9889
	-10125	-9860	-9886
+29	+10124	+9860	+9890
	-10127	-9861	-9888
+34	+10125	+9861	+9892
	-10128	-9863	-9889
+39	+10126	+9863	+9893
	-10126	-9863	-9889
+43	+10124	+9864	+9895
	-10125	-9864	-9892
+49	+10123	+9865	+9896
	-10123	-9865	-9891
+54	+10121	+9865	+9897
	-10122	-9865	-9893

SN009 Electronics Temp Test

Te	X	Y	Z
+17°C	+10124γ	+9854γ	+9878γ
	-10123	-9850	-9876
+23	+10124	+9855	+9882
	-10123	-9851	-9878
+27	+10125	+9856	+9883
	-10125	-9852	-9881
+31	+10127	+9856	+9884
	-10126	-9853	-9881
+36	+10128	+9858	+9886
	-10126	-9854	-9883
+38	+10130	+9859	+9888
	-10128	-9856	-9884
+47	+10130	+9859	+9891
	-10129	-9856	-9886

Table III

Sensor Temperature Test

1. Place the sensor assembly in the temperature chamber.
2. Heat the sensor assembly at +60^{o}C for 8 hours.
3. Remove the sensor assembly and install it in the coil system.
4. At selected intervals apply plus and minus 10,000γ to each axis in succession and read the magnetometer.
5. Repeat the above process after cooling the sensor at -30^{o}C for 8 hours.

SN007 Sensor Temp Test

Ts	X	Y	Z
$-28^{O}C$	+10027γ	+10685γ	+11513γ
	-10017	-10683	-11515
-10	+10025	+10693	+11520
	-10015	-10693	-11517
0	+10025	+10701	+11523
	-10020	-10699	-11523
+7	+10024	+10706	+11525
	-10019	-10702	-11525
+10	+10027	+10707	+11526
	-10017	-10702	-11526
+14	+10024	+10708	+11527
	-10018	-10706	-11527
+16	+10027	+10709	+11527
	-10018	-100707	-11527
+18	+10023	+10709	+11527
	-10021	-10708	-11528
+23	+10023	+10708	+11526
	-10618	-10705	-11525

Ts	X	Y	Z
+26	+10025γ	+10709γ	+11527γ
	-10015	-10706	-11525
+28	+10026	+10710	+11527
	-10014	-10707	-11526
+31	+10025	+10710	+11528
	-10015	-10709	-11526
+35	+10025	+10712	+11529
	-10015	-10710	-11527
+44	+10024	+10714	+11530
	-10016	-10711	-11529
+50	+10024	+10715	+11531
	-10014	-10712	-11530

SN008 Sensor Temp Test

Ts	X	Y	Z
-28°C	+10127$_Y$	+9853$_Y$	+9887$_Y$
	-10103	-9855	-9883
-10	+10116	+9859	+9894
	-10126	-9860	-9890
-1	+10117	+9863	+9895
	-10120	-9863	-9893
+7	+10121	+9863	+9898
	-10120	-9866	-9892
+11	+10122	+9865	+9898
	-10124	-9865	-9895
+13	+10119	+9864	+9897
	-10124	-9867	-9895
+16	+10123	+9865	+9897
	-10123	-9866	-9895
+18	+10124	+9865	+9899
	-10125	-9866	-9893
+19	+10124	+9866	+9899
	-10122	-9866	-9893

Ts	X	Y	Z
$+23^oC$	+10124γ	+9861γ	+9894γ
	-10124	-9863	-9891
+24	+10124	+9862	+9895
	-10125	-9862	-9891
+26	+10121	+9862	+9894
	-10126	-9863	-9891
+28	+10126	+9862	+9896
	-10125	-9864	-9891
+32	+10122	+9864	+9896
	-10125	-9864	-9893
+37	+10122	+9864	+9897
	-10126	-9865	-9894
+44	+10125	+9865	+9898
	-10124	-9866	-9895
+49	+10129	+9864	+9898
	-10131	-9865	-9895

SN009 Sensor Temp Test

Ts	X	Y	Z
-13°C	+10131γ	+9848γ	+9883γ
	-10129	-9845	-9878
-2	+10128	+9856	+9885
	-10127	-9852	-9884
+6	+10127	+9857	+9888
	-10126	-9853	-9883
+12	+10127	+9861	+9888
	-10127	-9856	-9885
+15	+10128	+9861	+9890
	-10128	-9857	-9884
+18	+10127	+9861	+9889
	-10127	-9858	-9886
+19	+10128	+9862	+9890
	-10126	-9858	-9886
+25	+10126	+9859	+9886
	-10125	-9855	-9882
+27	+10127	+8960	+9886
	-10125	-8956	-9882

Ts	X	Y	Z
+29	+10127γ	+9861γ	+9887γ
	-10126	-9856	-9883
+32	+10126	+9861	+9887
	-10125	-9857	-9884
+37	+10127	+9862	+9888
	-10124	-9858	-9883
+45	+10127	+9864	+9889
	-10124	-9859	-9885
+52	+10127	+9864	+9890
	-10125	-9860	-9884

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[1] J.J. Power, A digital offset fluxgate magnetometer for use in remote geomagnetic observatories, AFCRL-TR-73-0603, 1973.

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